

## EXECUTIVE SUMMARY

Nanoscale science and technology, often referred to as “nanoscience” or “nanotechnology,” are science and engineering enabled by our relatively new ability to manipulate and characterize matter at the level of single atoms and small groups of atoms. This capability is the result of many developments in the last two decades of the 20th century, including inventions of scientific instruments like the scanning tunneling microscope. Using such tools, scientists and engineers have begun controlling the structure and properties of materials and systems at the scale of  $10^{-9}$  meters, or 1/100,000 the width of a human hair. Scientists and engineers anticipate that nanoscale work will enable the development of materials and systems with dramatic new properties relevant to virtually every sector of the economy, such as medicine, telecommunications, and computers, and to areas of national interest such as homeland security. Indeed, early products based on nanoscale technology have already found their way into the marketplace and into defense applications.

In 1996, as the tremendous scientific and economic potential of nanoscale science and technology was beginning to be recognized, a federal interagency working group formed to consider creation of a national nanotechnology initiative (NNI). As a result of this effort, around \$1 billion have been directed toward NNI research since the start of FY 2001. At the request of officials in the White House Economic Council and agencies that are participating in NNI, the National Research Council (NRC) agreed to review the NNI. The Committee for the Review of the National Nanotechnology Initiative was formed by the NRC and asked to consider topics such as the current research portfolio of the NNI, the suitability of federal investments, and interagency coordination efforts in this area.

During the course of its evaluation, the committee was impressed with the leadership and level of multiagency involvement in the NNI. Specifically, the committee commends the leadership of the National Science Foundation (NSF) in the establishment of the multiagency Nanoscale Science, Engineering and Technology (NSET) committee as the primary coordinating mechanism for the NNI. NSET has played a key role in establishing research priorities, identifying Grand Challenges, and involving the United States scientific community in the NNI. It has also helped to sponsor a number of symposiums and workshops on advances in nanoscale science and technology, including the potential ethical, legal, and social issues of those advances.

In short, the committee finds that the leadership and investment strategy established by NSET has set a positive tone for the NNI. The initial success of the NNI can also be measured by the number of foreign governments that have established similar nanoscale science and technology research programs in response. Nevertheless, the committee has formulated a limited number of recommendations to further strengthen the implementation of NNI. Using information provided by the federal agencies involved in the initiative, the review panel considered structure and made 10 recommendations:

**Recommendation 1: The committee recommends that the Office of Science and Technology Policy establish an independent standing nanoscience and nanotechnology advisory board (NNAB) to provide advice to NSET members on research investment policy, strategy, program goals, and management processes.** With potential applications in virtually every existing industry and new applications yet to be discovered, nanoscale science and technology will no doubt emerge as one of the major drivers of economic growth in the first part of the new millennium. An advisory board could identify and champion research

opportunities that do not conveniently fit within any single agency's mission. It should be composed of leaders from industry and academia with scientific, technical, social science, or research management credentials.

**Recommendation 2: The committee recommends that NSET develop a crisp, compelling, overarching strategic plan. The plan would articulate short- (1 to 5 years), medium- (6 to 10 years), and long-range (beyond 10 years) goals and objectives. It should emphasize the long-range goals that move results out of the laboratory and into the service of society.** It should also include mechanisms for accelerating ideas into applications and identify applications for pilot projects. It should include a consistent set of anticipated outcomes for each theme and Grand Challenge and estimate time frames and metrics for achieving those outcomes.

**Recommendation 3: The committee recommends that NNI support long-term funding in nanoscale science and technology so they can achieve their potential and promise.** Establishing a proper balance between the short-term and long-term funding of nanoscale science and technology will be critical to realizing their full potential. Truly revolutionary ideas will need sustained funding to achieve results and produce important breakthroughs.

**Recommendation 4: The committee recommends that NSET increase multiagency investments in research at the intersection between nanoscale technology and biology.** The relevance of the NNI to biology, biotechnology, and the life sciences cannot be overstated. Cellular processes are inherently nanoscale phenomena. Our developing ability to manipulate matter at the nanoscale challenges us to construct nanodevices and systems capable of complex function similar to that of a cell. While we are far from achieving such complexity, we can already see applications of nanoscale science and technology that will have significant impacts in biotechnology and medicine. Barriers to interagency and interdisciplinary work must be overcome to enable such developments.

**Recommendation 5: The committee recommends that NSET create programs for the invention and development of new instruments for nanoscience.** Historically, many important advances in science come only after the appropriate investigative instruments became available. The NSET program should include analytical instruments for modeling, manipulating, tailoring, characterizing, and probing at the nanoscale.

**Recommendation 6: The committee recommends the creation of a special fund for Presidential grants, under OSTP management, to support interagency research programs relevant to nanoscale science and technology. These grants should be used exclusively to fund meaningful interagency collaborations that cross mission boundaries, particularly among the National Institutes of Health, the Department of Energy, and the National Science Foundation.** While it is appropriate for a federal agency to focus on its own particular mission, the breadth of NNI and its fields of impact—from new materials development to quantum computing and from cellular microbiology to national security—should compel agencies to form more meaningful cooperation in their nanoscale science and technology pursuits.

**Recommendation 7: The committee recommends that NSET provide strong support for the development of an interdisciplinary culture for nanoscale science and technology within the NNI.** Nanoscale science and technology are leading researchers along pathways formed by the convergence of many different disciplines, such as biology, physics, chemistry, materials science, mechanical engineering, and electrical engineering. To date, NSET member agencies have encouraged multidisciplinary collaborations, but creative programs are needed that encourage the development of self-contained interdisciplinary groups as well.

**Recommendation 8: The committee recommends that industrial partnerships be stimulated and nurtured, both domestically and internationally to help accelerate the commercialization of NNI developments. NSET should create support mechanisms for coordinating and leveraging state initiatives to organize regional competitive clusters for the development of nanoscale science and technology.** Nanoscale science and technology are ultimately about industrial competitive position, and the defining benefit is economic, as new technologies and products move from laboratories to commercial reality. The key to commercial success is to have processes that accelerate nano ideas into the commercial mainstream, thereby providing a timely return on the national investment in nanoscale science and technology.

**Recommendation 9: The committee recommends that NSET develop a new funding strategy to ensure that the societal implications of nanoscale science and technology become an integral and vital component of the NNI.** This is critical, because our success in developing, deploying, and exploiting nanotechnologies will require synchronous innovation in how we educate and train our workforce, manage our R&D system, and prepare for and adjust to the expected and unexpected social and economic impacts of the new technologies. Activities supported by the societal implications thrust area will help to ensure that this “second industrial revolution” produces social and economic as well as technical benefits.

**Recommendation 10: The committee recommends that NSET develop performance metrics to assess the effectiveness of the NNI in meeting its objectives and goals.** This should be done under the aegis of the OSTP. Measurable factors include quality, relevance, productivity, resources, and movement of research concepts toward applications. These factors should be developed with the advice of an appropriate advisory council, perhaps the suggested NNAB, in conjunction with the various agencies involved in the NNI.